ACOUSTICALLY DAMPED COMPOSITE CONSTRUCTION FOR THE FORWARD PORTION OF A ROCKET OR MISSILE

TECHNICAL FIELD

[0001] The present invention generally relates to an acoustically damped composite, and more particularly relates to an acoustically damped composite for use in a launch vehicle rocket fairing.

BACKGROUND

[0002] Expendable launch vehicle rockets are used to transport satellites and other payloads into space for a minimum of cost. Payload fairings are the 'nose cone' structures comprising the forward portion of the launch vehicle and are the part of the launch vehicle in which the payload is stored prior to the vehicle leaving the earth's atmosphere. The forward portion of the launch vehicle comprising the payload fairing can be up to $1/3^{rd}$ of the overall length of the launch vehicle and has a unique aerodynamic loading scenario that makes this invention possible. Payload fairings protect the payload cargo from heat buildup, electro-magnetic interference, collapse pressures due to wind loads, and contamination from dust and other particles as the launch vehicle is boosted through the earth's atmosphere. Payload fairings also protect the payload cargo from acoustic impingement during the first few seconds of liftoff; the vibration, shock, and noise generated during liftoff can easily damage satellites or other vibration-sensitive cargo. Payload fairings are often not needed when the rocket leaves the earth's atmosphere and are discarded once the rocket reaches a low density atmosphere in order to drop unnecessary mass from the rocket.

[0003] Current composites used for payload fairing construction typically consist of a rigid core sandwiched between two outer, or face sheets of a rigid material. The face sheets, typically an epoxy impregnated graphite, are both about 3 millimeters (about 0.125 inches) thick in cross-section, and the rigid core between them, typically high density foam, is about 19 millimeters (about 0.75 inches) thick in cross-section. The rigid face sheets are bonded to the foam layer with rigid epoxy. This method of layered construction is strong, thin, and

lightweight, but unfortunately it is too rigid to provide any shock or vibration damping. Present methods for limiting acoustic intrusion into the payload fairing consist mostly of add-on systems. The payload fairing is often lined with a passive system such as an acoustic blanket made from fiberglass batting or acoustically damping foam. This system must also meet stringent contamination control requirements, must be self venting away from the payload compartment, and survive the extreme loading conditions such as temperatures from –20 degrees Fahrenheit to +350 degrees Fahrenheit, with up to 1000 g's acceleration loading during the fairing's pyrotechnic separation event. And, all of this must be qualified for flight in full-scale acoustic, shock, structural, and separation tests conducted in high altitude vacuum chambers. Active damping solutions such as a helmholtz resonator systems employed in payload fairings will undergo a second set of flight qualifications. The problem with any of these systems is that they add a great deal of weight and cost to the payload fairing and yet they are only functionally necessary for the first few seconds of liftoff. They often also decrease the space for a payload within the fairing. The added weight and volume of these add-on systems thus place limitations on the size and weight of payloads that can be transported into space by the launch vehicle rocket. In a typical scenario, a payload customer will give the launch vehicle provider a requirement for stringent acoustic environments for this particular mission. In order to win the launch contract, the launch vehicle provider will agree to meet these requirements by providing an add-on system to the launch vehicle. The cost of this add-on system is paid for out of the launch vehicle provider's profits and the weight hit, if small, will come out of launch payload and then the payload customer must make up the difference by reducing propellant margins or by other means.

[0004] Accordingly, it is desirable to provide an improved material for launch vehicle fairings that will provide the necessary strength to handle the loads imposed on the fairing and will also function to limit the acoustic impingement on payloads during launch, and provide an easy to clean contamination free surface, without adding undue weight and cost to the construction of the fairing. Furthermore, other desirable features and characteristics of the present invention will become apparent from the subsequent detailed description and the appended claims, taken in conjunction with the accompanying drawings and the foregoing technical field and background.

BRIEF SUMMARY

[0005] An apparatus is provided for an acoustical composite construction especially designed for use in a launch vehicle fairing. The acoustical composite construction includes a low density core material having a first side and a second side. A first sheet of rigid face material is bonded to the first side with a visco elastic adhesive, and a second sheet of rigid face material is bonded to the second side with a visco elastic adhesive. The visco elastic material allows the first and second face sheets to move relative to each other. The low density core material can be selected to have a thickness approximately equal to a quarter wave length of the dominant acoustic frequency to which the fairing will be exposed during launch to dampen that frequency by impedance mismatch.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] The present invention will hereinafter be described in conjunction with the following sole drawing figure in which FIG. 1 schematically illustrates, in cross section, an acoustically damped payload faring composite.

DETAILED DESCRIPTION

[0007] The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary or the following detailed description.

[0008] An acoustically damped composite construction particularly useful in payload fairings incorporates passive means of damping acoustic vibration and shock into the composite construction itself. In accordance with one embodiment of the invention the face sheets of the composite construction are bonded to a lightweight core with a bonding material such as a visco elastic adhesive material. Rather than have the face sheets rigidly bonded to a lightweight core, the visco elastic adhesive allows the face sheets to move slightly relative to each other and to the lightweight core, absorbing acoustic vibration and producing heat as a byproduct. The thickness of the lightweight core layer is preferably

selected to be one quarter of the wavelength of the dominant frequency the payload fairing composite is designed to minimize. The selected thickness creates an impedance mismatch between the face sheets, causing the face sheets to respond to the dominate frequency by vibrating out of phase and causing destructive interference. The acoustically damped composite construction, while thicker than traditional payload fairing constructions, eliminates the need for add-on acoustic treatments, weighs about the same overall as a traditional payload fairing system, and is strong enough to handle the primary and secondary loads placed on a payload fairing composite during launch. Incorporating the acoustic damping necessary to protect payload cargo from damaging shock and vibration into the composite construction itself also reduces the cost of the overall payload fairing system thereby adding value for both the launch vehicle provider and the payload customer.

[0009] FIG. 1 illustrates in cross section an acoustically damped composite construction 8 in accordance with an embodiment of the invention. Such a composite material is especially advantageous for use in the fabrication of launch vehicle fairings, although it is also useful in other applications that require passive acoustic protection such as in the fabrication of airplanes, motor vehicles, trains, and the like. In the remainder of this detailed description the inventive acoustic composite construction will be referenced, without limitation, to its application to the fabrication of a launch vehicle payload fairing and will be referred to as a fairing composite or as a payload fairing composite.

[0010] In accordance with one embodiment of the invention, acoustically damped payload fairing composite 8 includes outer face sheet 10, inner face sheet 12, lightweight core 14, outer visco elastic adhesive layer 16, and inner visco elastic adhesive layer 18. Outer face sheet 10 forms the exterior of the payload fairing and is exposed to the atmosphere; inner face sheet 12 forms the interior of the payload fairing. Outer face sheet 10 and inner face sheet 12 are bonded to lightweight core 14 with outer visco elastic adhesive layer 16 and inner visco elastic adhesive layer 18, respectively. Outer face sheet 10 and inner face sheet 12 are preferably constructed from a rigid resin impregnated fiber, and more preferably from a graphite epoxy, such as Stesalit PN900, Cycom 5210LO or the like. Both face sheets are thin, preferably between about 1.6 millimeters and 12.7 millimeters (about 0.0625 inches and 0.5 inches) thick in cross section, and most preferably both face sheets are the same thickness and are about 3 millimeters (about 0.125 inches) thick in cross section. In accordance with one embodiment of the invention the face sheets are made of a plurality of layers or plies of fiber mat. The number of plies in the outer and inner face sheets, as well

as the orientation and direction of the plies in both face sheets, may be varied in known manner in order to meet requirements for strength, stiffness, or the like.

[0011] The material bonding the face sheets to the lightweight core, in the preferred embodiment illustrated above, is described as visco elastic materials. Outer visco elastic adhesive layer 16 and inner visco elastic adhesive layer 18 may be, for example, V112 from the 3M Corporation or the like. Both outer visco elastic adhesive layer 16 and inner visco elastic adhesive layer 18 may be between about 0.8 millimeters and 3 millimeters (about 0.03 inches and 0.125 inches) thick in cross section, though it is preferable that both visco elastic adhesive layers are the same cross-sectional thickness and are about 3 millimeters (about 0.125 inches) thick in cross-section. Other bonding materials may also be employed in the acoustic composite construction in accordance with the invention as long as those bonding materials allow for relative movement between the outer and inner face sheets.

[0012] Lightweight core 14 is constructed from a low-density material, preferably low density foam that is less than about 48 kilograms per cubic meter (about 3 pounds per cubic foot) such as HT50 from the Divinylcell Corporation or the like. In accordance with one embodiment of the invention the cross-sectional thickness of lightweight core 14 is chosen such that outer face sheet 10 and inner face sheet 12 are placed a distance apart (in cross section) that is equal to one quarter the wavelength of the dominant acoustic frequency to which the acoustically damped payload fairing composite will be exposed. For example, if the dominant acoustic frequency to which the acoustically damped payload fairing composite 8 will be exposed is a frequency of 500 hertz, the lightweight core 14 would be about 15-16 cm (about 6 inches) in thickness. Placing the two face sheets this distance apart creates an impedance mismatch between the face sheets, damping the dominant frequency to which the acoustically damped payload fairing will be exposed. When coupled with the broadband acoustic reduction from the visco elastic construction, the payload fairing now provides good overall acoustic reduction across the entire low frequency region.

[0013] Acoustically damped payload fairing composite 8 is relatively inexpensive to produce because it does not need the expensive auto-claving that many traditional prior art payload fairing composites require. Outer face sheet 10 and inner face sheet 12 are first bonded to lightweight core 14 with outer visco elastic adhesive layer 16 and inner visco elastic adhesive layer 18, respectively. The assembled acoustically damped payload fairing composite is then placed in a vacuum-bag and cured. The curing used on the acoustically

damped payload fairing composite may be, for example, oven curing, air curing, or the like. Those of skill in the art will recognize that additional methods for construction payload fairing composites that do not require auto-claving are also applicable here.

[0014] Traditional payload fairing composites use a high density foam core that is less than 25.4 millimeters (one inch) thick, making lightweight core 14, as well as acoustically damped payload fairing composite 8, much thicker than a typical payload fairing composite. However, using a low density material such as HT50 from the Divinylcell Corporation instead of the high density foam core of the prior art (typically greater than 112 kg/m^3 (7 lbs/ft^3) and often as high as 193 kg/m^3 (12 lbs/ft^3)), makes the acoustically damped payload fairing composite weigh about the same as a traditional payload faring composite. Also, despite the greater thickness of acoustically damped payload fairing composite 8 compared to traditional payload fairing composites, eliminating the need for acoustic blankets or an add-on damping system inside the payload cargo area maximizes the payload cargo volume for a given outside volume. Even though the low density material used in lightweight core 14, by itself, is not as strong as the prior art higher density foam, the wider spacing between the face sheets in the acoustically damped payload fairing composite in accordance with the invention adds significant stiffness to the structure and makes the inventive composite construction strong enough to handle the particular loads to which a payload fairing is exposed. High collapse pressure loads and shear crimping that are the primary means of structural failure for a payload fairing or the forward portion of a rocket or missile construction. The secondary line loads, namely a combination of bending, shear, and axial loads caused by atmospheric loads and friction, are low in the forward portion of a rocket or missile in comparison to the rest of the launch vehicle are. Therefore, the low density foam core which has proportionally lower strength can be used in the forward portion of a rocket or missile due to the lower line-loads while the increased thickness of the composite construction acts to provide higher strength and stiffness to the forward portion of a launch vehicle to satisfy its primary loading scenario.

[0015] While at least one exemplary embodiment has been presented in the foregoing detailed description, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing the exemplary embodiments. It should be

understood that various changes can be made in the function and arrangement of elements without departing from the scope of the invention as set forth in the appended claims and the legal equivalents thereof.